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IGY BULLETIN

A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

IGY Antarctic Oversnow Traverses

Although 11 nations have established 38 new scientific stations in the Antarctic for the IGY, observations made at these widely-distributed stations can furnish only a portion of the geophysical data needed for a complete understanding of this 6,000,000-square-mile region of ice and rock. To fill some of the major gaps, a series of oversnow scientific traverses were organized as part of the US-IGY Antarctic Program for the summer seasons of 1957–58 and 1958–59.

Three major oversnow traverses scheduled for the 1957–58 summer season by the US-IGY have been completed—the Ross Ice Shelf traverse from IGY Little America Station; a traverse of parts of Marie Byrd Land and the Ellsworth Highland from IGY Byrd Station; and a traverse across the Filchner Ice Shelf and parts of Edith Ronne Land from IGY Ellsworth Station (see Fig. 1). They were preceded in January and February 1957 by a tractor-train traverse from Little America to Byrd Station, 647 mi eastward over the ice cap. Glaciologic and seismologic measurements were made on this first traverse; experimental and logistic procedures and techniques were tested and perfected. A full four months of field work is planned for each of the summer seasons, which begin in October and end in March, despite an interruption about mid-season for the annual replacement of personnel.

Scientific Objectives

In the traverse program seismic techniques are used to measure the thickness of the ice and to determine the character of the subglacial floor and of exposed land areas. Ground control, for subsequent survey operations, is established wherever rock outcrops occur. Core, pit, and surface studies are made to provide data on snow stratigraphy and on the movement, volume, thermal and hydrologic regimen, recent mass changes, and crystallography of the ice.

Gravity measurements, partly in association with the seismic work, and measurements of the earth's magnetic field strength and of magnetic compass variations are included in the basic traverse programs. Standard meteorological information is obtained on all traverses for transmittal to the IGY Antarctic Weather Central at Little America Station. (*Bulletin No. 4, October 1957*, contains a detailed report on the Weather Central.) Airborne seismic and glaciological traverses, to make spot measurements in areas inaccessible to surface parties, are also part of the program.

Although geologic study reveals that the Antarctic ice mantle was once about 1000 ft thicker than it is now, it is not yet known whether the total ice mass is at present increasing or decreasing. Some estimates suggest that it may be in a state of approximate equilibrium, but a large

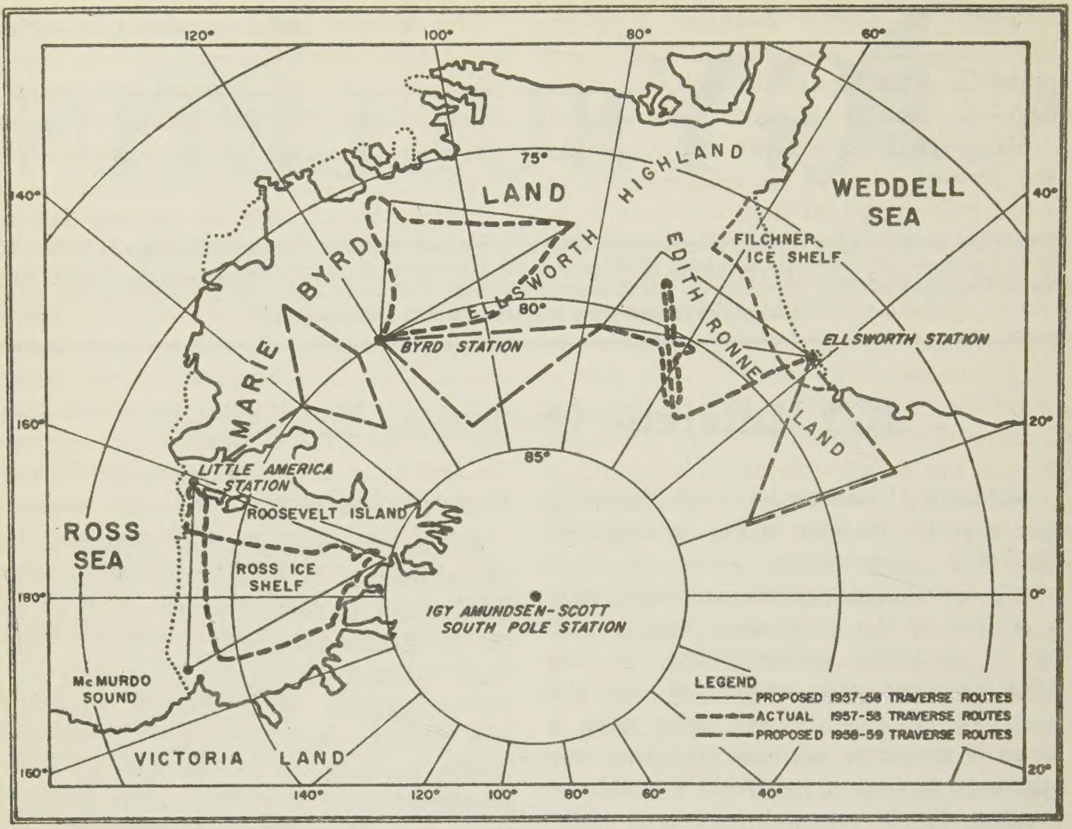

Fig. 1. *Map of Portion of Antarctica Showing Major US-IGY Oversnow Traverse Routes. Lines representing actual routes of 1957—58 traverses are approximate. Dotted lines represent approximate seaward boundaries of ice shelves. The inland boundary of the Filchner Ice Shelf, shown by short-dash line, is also approximate.*

body of detailed glaciological and micrometeorological information from both the fixed stations and a broad network of oversnow and airborne traverses must be accumulated and analyzed before final conclusions can be reached.

The early traverse from IGY Little America Station to Byrd Station resulted in the first extensive evidence that the Antarctic continent is overlaid with a far greater volume of ice than long thought. (Byrd Station, about 5000 ft above sea level, rests on about 10,000 ft of ice.)

Gravity and seismologic data obtained on these traverses may show whether the sub-sea-level portion of the ice sheet, such as exists beneath Byrd Station, occurs in fjord-like depressions similar to those found to exist under the Greenland ice cap and Queen Maud Land or indicates the presence of a great frozen sea in West Antarctica.

Data acquired on the traverses will also contribute to knowledge of the relationships between Antarctic ice and the supply and movement of cold ocean waters, as well as between the ice and Southern Hemisphere weather and climate.

1957–58 Traverses

IGY Little America Station—The traverse party from Little America had as its objective during the past season the study of the mass and volume, thickness, hydrologic economy, morphology, and structure of the Ross Ice Shelf. The depth to the sea bottom beneath the floating ice shelf was

measured by seismic methods, investigations were made of mountain ranges and peaks along the edge of the shelf, and wind-drift—or sastrugi—patterns were studied.

The Ross Ice Shelf extends more than 400 mi into the Ross Sea embayment from a point about 300 mi from the South Pole. Its maximum width is approximately 500 mi and its area about 160,000 square mi. Recent seismic studies by IGY scientists at Little America Station made in the vicinity of the station but away from the edge of the shelf, show an ice thickness ranging from nearly 790 to about 1050 ft. The ocean bottom was shown to be about 2070 to 2155 ft below the ice surface, indicating that this part of the shelf floats on well over 1000 ft of water.

Gravity measurements made this summer at IGY Little America Station indicate vertical movement of the shelf of several feet. Motion is very small 7 mi from the station and entirely absent at distances of 20 to 30 mi. It has been estimated that the shelf moves seaward at the rate of about 5 ft/day. The additional seismic and gravity measurements accumulated on the Ross Ice Shelf traverse will ultimately permit a more complete synthesis of the physical character of the entire shelf.

It is apparent from ice-fracture patterns that the Ice Shelf is grounded in many places. Although the islands on which it is grounded do not generally penetrate the ice, they may be identified by hinge cracks, higher elevations, and ice-fracture patterns. These features were mapped wherever possible along the traverse route.

Initial plans for the Ross Ice Shelf traverse prescribed a triangular route from Little America Station westward to McMurdo Sound, southeast to the Beardmore and Liv Glaciers at the southern edge of the shelf, and northeastward back to Little America Station (see Fig. 1). This route was generally adhered to, although McMurdo Sound was by-passed to maintain the planned time schedule, and several deviations were made for special studies.

The traverse party, consisting of eight men led by Albert P. Crary, Station Scientific Leader at Little America and Deputy Chief Scientist for the USNC-IGY Antarctic Program, left its home station on October 24, 1957.

Reports issued while the traverse was in progress listed, through January 1958, a total of 34 seismic, 179 gravity, and 160 magnetic stations occupied; 26 glaciological pit studies made; 130 ramsonde measurements taken (the ramsonde, or ram penetrometer, is an instrument for determining physical properties of the snow by recording the amount of force required to drive a rod a given distance into it); and weather observations made at 281 stations. In addition, ice temperature and density were measured at a depth of about 30 ft in 31 drill holes, 55 ft in one drill hole, and 65 ft in three drill holes.

R. L. Viets, geomagnetician at Little America Station, visited the traverse party briefly at 82°S, 170°E, where he was able to make successful magnetic field observations with a magnetometer provided by New Zealand IGY scientists.

Elevation of the ice surface was measured continuously along the traverse route by the "altimetry leap-frog method," which employs three crews to make successive atmospheric pressure measurements at each site. Sites occupied are five miles apart. This method provides enough data for each position to permit corrections for fluctuations in atmospheric pressure, allowing much more accurate altitude determinations than would be possible with single observations.

Employing this technique, the Ross Ice Shelf traverse party found that the shelf's elevation varies overall by about 60 ft. In general, however, the Ice Shelf appeared virtually featureless. Only two small islands, situated just west of Roosevelt Island, and two small depressions broke the evenness of the ice surface during the first leg of the route.

The traverse party returned to IGY

Table 1. *Seismic Data Obtained on Byrd Traverse 1957—58*

Lat. (S)	Long. (W)	Elev. above sea level (ft)	Ice Thickness (ft)	Remarks
79°11′	116°36′	5625	7955	Southwest border of hilly region
78°44′	114°57′	5935	6890	Maximum surface elevation
78°30′	114°50′	5775	5165	Point of minimum ice thickness; highest point of rock floor in 20 mile zone; only area with rock floor above sea level
77°54′	113°16′	4980	8200	Basin area
77°28′	112°22′	4625	6990	Second hilly region
76°48′	112°50′	4215	9285	Basin adjoining mountain
76°19′	111°46′	4920	0	Exposed rock on mountain
76°58′	109°07′	3900	7695	Represents 100-mile, flat surface and ice bottom east of mountain
77°27′6″	100°26′	4625	10,825	Maximum ice thickness

Little America Station on February 13, 1958, after 113 days in the field. The overall length of the traverse was 1450 mi.

IGY Byrd Station—The broad objective of the Byrd Station traverse for the 1957–58 summer season was to determine the general nature of the ice sheet and of protruding mountains in eastern Marie Byrd Land and in the Ellsworth Highland to the east of Byrd Station. Although specific types of measurements were similar to those made on the Ross Ice Shelf traverse, the existence of thousands of feet of inland ice resting on a bedrock surface in the region covered by the Byrd party constituted a major environmental difference.

The Byrd Station traverse party, led by Vernon Anderson, IGY glaciologist, departed on November 19, 1957. Radio schedules were arranged with the Ellsworth traverse group for exchange of information.

Excellent seismic reflection data were obtained throughout the traverse. Table 1 gives ice thicknesses and elevations of the surface at representative points along the first and second legs of the traverse; at only one of these locations does the subglacial floor rise above sea level, and at the last location the ice thickness, surface elevation, and bedrock depth are similar to those at Byrd Station. At distances of 100–200 mi west of the Sentinel Mountains, the apex of the second and third legs of the traverse, ice thicknesses were generally more than 10,000 ft; the maximum measured was 11,610 ft. The seismic records for most of the traverse route indicate rugged, variable topography characterizing a subglacial floor almost everywhere below sea level.

The Byrd Station traverse party collected samples of volcanic rocks and lichens in the region of an unnamed mountain range about 250 mi northeast of Byrd Station. One unusual biological observation was the discovery of penguin tracks along the traverse route at a point more than 150 mi from the nearest known coast.

Although figures for the entire traverse are not yet available, an idea of the party's experimental activities may be formed from the following list compiled for the month of December, 1957. During that period, the traverse party made 13 short refraction profiles, 110 gravity and magnetic readings, 12 glaciological pit studies, and 55 intermediate-depth ramsonde measurements. Six days were spent at the Sentinel Mountains making long seismic-refraction profile studies and collecting rock samples. After leaving the Sentinels, increasing surface noise interfered with seismic work.

At the Sentinels, study of a nunatak (isolated peak or hill projecting through a glacial surface) indicated a former ice level 800 ft above the present surface. Investigations were made and rock samples collected at five nunataks. Glaciological studies along the traverse route showed an ac-

cumulation of about 20–30 inches of snow during the past year.

The traverse ended on February 23, 1958, with the return of the party to IGY Byrd Station after 96 days in the field and a trek of about 1200 mi.

IGY Ellsworth Station—The Ellsworth Station traverse investigated the Filchner Ice Shelf and the inland ice of Edith Ronne Land, combining the types of measurements made by both the Little America and Byrd traverses. An important goal of this traverse was to occupy a point that could also be reached by next summer season's Byrd Station traverse, thus providing a link for the correlation of data.

The traverse party left IGY Ellsworth Station on October 28, 1957, led by Edward C. Thiel, glaciologist. The party had been held up several days while airborne efforts were made to find a safe passage through a heavily crevassed area in the first 50 miles south of Ellsworth Station. A crevasse-free passage towards the east and with elevations of 700 to 3000 ft above sea level was found.

The party deviated about 120 mi from the planned route to make geological studies and collect rock specimens at a newly reported mountain range. The range, estimated to be 11,000 ft high in places, is reported to be about 400 mi from the South Pole, trending east-west throughout its length of about 100 mi. It was discovered from the air by Finn Ronne, then scientific leader at IGY Ellsworth Station.

On December 22, another mountain range, first sighted on a reconnaissance flight early in 1957, was reached. These mountains have an average height of 6500 ft and extend east-west along 82°33′S for about 30 mi, between 51° and 55°W. Black bands were noted high on the mountains, and a 5000-ft escarpment was discovered on the southern side.

A 3200-ft, ice-covered island extending for about 230 mi south and west from Gould Bay was observed for the first time. Seismic soundings showed the land surface beneath the island's ice mantle to be hundreds of feet above sea level. Other islands, whose contours were not fully delineated, were seen still farther westward. They appear to tie in with land in the Sweeney and Lowell Thomas Mountains at the western end of the Filchner Ice Shelf.

The traverse party encountered several crevasse fields along the route. In early January 1958, after reaching a difficult crevasse field at 78°40′S, 69°W, about 80 mi from Mt. Hassage, at the apex of the second and third legs of the traverse, the party was evacuated by air. A relief party had been flown in to attempt to continue the traverse. To that point, the traverse had covered 816 mi, including a large portion of the Filchner Ice Shelf and considerable inland stretches. The relief party backtracked in an effort to find an open route to Ellsworth Station. It then turned southward to the midpoint station, where the vehicles and equipment were cached for use by next year's party.

Other traverses: 1957–58—Personnel remaining at US-IGY Antarctic stations conducted several short traverses in the vicinities of their stations during the 1957–58 Antarctic summer season. The aims were basically similar to those of the major traverses.

The airborne seismologic traverse program was inaugurated with flights into Victoria Land, on the ice cap east of McMurdo Sound. Original plans scheduled landings at 50-mile intervals. Between January 2 and 22, 1958, three stations were occupied for the purpose of making glaciological, gravity, and seismological observations. Station A was occupied at 77°33′S, 158°30′E, at an elevation of 7750 ft, Station B at 77°09′S, 155°05′E and an elevation of 8300 ft, and Station C at 77°22′S, 139°48′E, elevation 8850 ft. Results obtained at these and other stations occupied in this program will be compared and correlated with those obtained on the oversnow traverses.

A combined New Zealand-United King-

dom Trans-Antarctic Expedition, using the US-IGY South Pole Station as a linkage point, was conducted during the past Antarctic summer, completing the first continental crossing of the Antarctic.

The New Zealand group, under the direction of Sir Edmund Hillary, left Scott Station (N. Z.), at the northwest corner of the Ross Ice Shelf, on October 14, 1957. Its purpose was to establish supply dumps for the United Kingdom party. It reached the Pole, about 1200 mi distant, on January 4, 1958. The United Kingdom party, led by Vivian E. Fuchs, left Shackleton Station, on the Weddell Sea, on November 24, 1957; it arrived at the South Pole on January 19, 1958. This was the first time the regions between the Weddell Sea and the South Pole, a distance of more than 2000 mi, had been crossed overland.

The party left IGY South Pole Station on January 24, and reached Scott Station, the terminus of the traverse, on March 1, 1958. Seismic studies made by the Fuchs party should provide the first profile of the ice thickness, surface elevations, and subglacial surface across Antarctica from the Weddell Sea to the Ross Sea.

During the 1957–58 summer season, USSR-IGY oversnow trail parties conducted traverses into the interior of Antarctica from IGY Mirny Station, on the Queen Mary Coast in East Antarctica; their goal was to establish scientific stations at the south geomagnetic pole and the "pole of inaccessibility." One party reached 78°27′S, 106°52′E, a few miles from the geomagnetic pole, on December 16, 1957. The USSR-IGY Vostok II Station was established at this location, 10,500 ft above sea level. This party reported winds up to 134 mph at a point along the traverse route 200 mi west of Mirny. Another party reached 78°24′S, 87°35′E, about 425 mi from the pole of inaccessibility, on February 12, 1958, where it established the USSR-IGY Sovietskaya Station. This station, deep in the interior of Antarctica, is at an elevation of about 12,100 ft.

Planned US-IGY Traverses

Personnel of IGY Little America, Byrd, and Ellsworth Stations will conduct further oversnow traverses during the 1958–59 Antarctic summer. The Little America group plans a roughly diamond-shaped traverse route on the Rockefeller Plateau north and west of Byrd Station, from 80°S, 140°W to 77°S, 130°W; from there to 80°S, 125°W in the vicinity of Byrd Station; then back to the starting point.

The Byrd Station party will cover a route in the southern part of the Ellsworth Highland, from the station to about 81°S, 75°W, to occupy a point first occupied by the 1957–58 Ellsworth Station traverse. It will then proceed to Horlick Mountain, at 85°S, 90°W, and back to Byrd Station. The total distance to be covered on the Byrd Station traverse is 1065 mi.

The route originally proposed for the 1958–59 Ellsworth traverse is heavily crevassed. As a result, alternative routes are under consideration.

Organization and Logistics

Each major US-IGY traverse party was staffed with two glaciologists (except the Ross Ice Shelf party which had three), two seismologists, one gravity observer, and support personnel. In each party were personnel capable of driving and maintaining the vehicles, navigating, operating and maintaining radios, cooking, administering first aid, and maintaining a field camp. Additional scientific personnel were added occasionally for special studies.

Indispensable airborne and other logistic support for the traverses was supplied by U. S. Navy Task Force 43 under the command of Rear Admiral George Dufek.

The vehicles used were Tucker Model 743 Sno-Cat Freighters, US Army M29C Weasels, and cargo sleds. Each Sno-Cat is capable of hauling 2300 lbs of cargo and passengers and of towing up to 2½ tons at cruising speeds of 10–15 mph. The four-passenger Weasels can tow sled loads of as

much as two tons. The Sno-Cats and Weasels are equipped with heated cabs for both living and working quarters. During the 1957–58 traverses, each party used three Sno-Cats towing cargo sleds.

Lead vehicles of all traverse parties were fitted with electronic crevasse detectors to assist in finding safe routes. Gyrocompasses, which permit navigation independently of the earth's magnetism, were used instead of magnetic compasses, generally very unreliable in polar regions. Each oversnow traverse party carried one high-frequency radio transmitter having a range of .35 to 9.05 mc and capable of 125-watt CW (continuous wave) or 40-watt voice transmission. At least one medium-to-high frequency receiver was also carried by each party, as well as a portable 100-watt unit capable of 2- to 18-mc CW or voice transmission and reception.

Ski-equipped aircraft were used in advance of the traverse parties to help them choose the easiest and safest routes, providing reports and aerial photographs of the terrain to be crossed.

Experience has shown that such oversnow traverse parties can operate for distances of about 300 mi on the fuel they can carry. Hence, the total range of operation, 1200 mi or more for the major traverses, depended on airborne fuel depots established at the required intervals and on airdrop support when needed. In other respects, each traverse unit was as self sufficient as possible, carrying with it spare radio equipment and emergency gear to be used in case a vehicle was lost or damaged.

Physical obstacles, such as crevasse fields, and scientific considerations dictated some departures from original traverse routes.

World Warning Agency Decisions

October 3, 1957–January 1, 1958

During the first three months of the IGY, 14 periods of Alerts and 4 SWI (Special World Intervals) were declared by AGIWARN, the IGY World Warning Agency, operated by the National Bureau of Standards at Fort Belvoir, Virginia, near Washington, D. C. (See *Bulletin No. 5, November 1957*, for details of this first three-month IGY period.)

During the next three-month period, solar activity was in general lower; only six periods of Alert, totalling 23 days, and two SWI, totalling four days, were declared. One of the SWI was unsuccessful in that no major solar disturbance with associated terrestrial effects followed. During the other SWI a short but relatively severe geomagnetic disturbance took place.

In the second three months, sunspot activity, as measured in terms of the provisional Zurich monthly sunspot number, continued high, and the smoothed sunspot number continued to rise.

Following are the Alerts, SWI, geomagnetic disturbances, and major flares that occurred from October 3, 1957, to January 1, 1958. Alerts and SWI are numbered according to a simple chronological system in use by AGIWARN. The numbers in this list continue serially from the last Alert, number 10, which started on September 27, and the last SWI, number 6, which started on September 12, 1957. (The list of Alerts and SWI which appeared in *Bulletin 5*, p. 14, may be modified to reflect this numbering system.)

Oct. 9 034x Class 3 flare
Oct. 14 1600 Alert #11 starts
Oct. 16 0152 Class 3 flare; sudden ionosphere drop-out and gradual recovery
Oct. 16 0416 Class 3 flare
Oct. 19 064x Class 3 flare
0700 Class 3 flare

Oct. 20	1600	Alert #11 finishes
	1637	Class 3+ flare
	1644	Class 3+ flare
	1700	Class 3 flare; sudden ionosphere drop-out and gradual recovery
Oct. 21	1600	Alert #12 starts
Oct. 22	0001	SWI #6 starts
Oct. 23	062x	Class 3 flare; sudden ionosphere drop-out and gradual recovery
	1600	Alert #12 finishes
	2359	SWI #6 finishes
Nov. 12	1600	Alert #13 starts
Nov. 15	1600	Alert #13 finishes
Nov. 24	0848	Class 3+ flare
	1600	Alert #14 starts
Nov. 26	0001	SWI #7 starts
	1455	Moderate magnetic storm starts
Nov. 27	12xx	Magnetic storm finishes
	1600	Alert #14 finishes
	2359	SWI #7 finishes
Dec. 5	065x	Class 3 flare
Dec. 14	125x	Class 3 flare
Dec. 15	1600	Alert #15 starts
Dec. 16	1127	Class 3 flare
Dec. 18	0450	Class 3 flare
Dec. 21	1600	Alert #15 finishes
Dec. 26	1600	Alert #16 starts
Dec. 29	1600	Alert #16 finishes

As an illustration of how AGIWARN uses information and advice from other centers, an excerpt from a report by R. C. Moore, Director of AGIWARN, is given below. The code groups have the following meaning:

ALNIL—No Alert
ALBEG—Alert begins
ALCON—Alert continues
ALFIN—Alert finishes
INBEG—SWI begins
INCON—SWI continues
INFIN—SWI finishes

"For several days prior to November 22 the sun was relatively quiet. Without exception the nine centers (Anchorage, Boulder, Darmstadt, Kokubunji, Moscow, Nederhorstdenberg (NERA), Paris, Prague and Sydney) advised that no Alert be started (ALNIL); the AGIWARN decision on each of these days was ALNIL.

November 22: Eight centers suggested ALNIL, while Sydney wanted to begin an Alert (ALBEG). A solar region then well west of central meridian produced several flares, but none of great interest. The AGIWARN decision was ALNIL.

November 23: Seven centers advised ALNIL; Moscow's advice was ALBEG; no message was received from Paris. The western region's activity level appeared to be rising, but the situation did not seem to warrant the starting of an Alert, so the AGIWARN decision was ALNIL.

November 24: Boulder, Moscow and NERA advised ALBEG; Anchorage, Darmstadt and Prague advised ALNIL. Kokubunji and Sydney suggested ALBEG also but the messages arrived too late, and no message was received from Paris.
By now the western region was no longer active, but an eastern area which had appeared at the east limb of the sun November 20 and had exhibited only minor activity during the first four days of its transit suddenly became interesting. It produced a series of flares ranging in importance from 2 to 3 plus. This flare activity was accompanied by well observed major radio noise events.
Based on the above activity, plus encouragement from three of the six centers, AGIWARN began an Alert.

November 25: Five centers advised that the Alert be continued (ALCON) and four centers (Darmstadt, NERA, Paris and Sydney) suggested that a Special World Interval be started (INBEG).
Although only one of the four centers (NERA) which suggested INBEG had advised ALBEG the preceding day, the timing of the events which had precipitated the November 24 ALBEG seemed to warrant the starting of an Interval. The AGIWARN decision, therefore, was INBEG.

November 26: The Interval began at 0001 UT and a sudden commencement of geomagnetic disturbance started at 1455 UT. Eight centers advised that the Interval be continued (INCON) and one (Paris) suggested it be finished (INFIN) but the Alert continued (ALCON). The AGIWARN decision was INCON.

November 27: Five centers advised that the Interval be stopped but suggested that the Alert be allowed to continue. Four centers (Darmstadt, Moscow, Prague and Sydney) thought that the Interval should continue.
The region associated with the disturbance had produced no major flare activity since November 24. In addition, the storm appeared to be subsiding quickly. The AGIWARN decision, therefore, was ALFIN INFIN.

November 28: The disturbance was officially ended about 1200 UT November 27. All centers advised ALNIL and the sun continued to be quiet. The AGIWARN decision was ALNIL."

Cosmic-Ray Balloon Experiments

Soft Radiation Associated with Auroras and Geomagnetic Activity

As long ago as the summer of 1953, L. H. Meredith, M. B. Gottlieb, and J. A. Van Allen detected the presence of new "soft" (low energy) radiation at altitudes above 50 km by means of Geiger counters in a series of rockoon (balloon-launched rocket) experiments. During the summers of 1953, 1954, and 1955, Van Allen's group observed the latitude distribution and temporal variation of the effect; these strongly suggested that it was auroral-associated, even though all flights were made in the daytime, and no direct correlation with visual auroras could be shown.

Using additional experimental data taken with a scintillation detector, Van Allen concluded that the soft radiation was probably X-rays in the 10–100 kev (1–0.1Å) range rather than protons or electrons. This was supported by laboratory experiments and energy calculations which suggested that the X-rays might be produced as "bremsstrahlung" from incoming electrons penetrating to 90–110 km in the atmosphere. (When a particle having kinetic energy in the X-ray range suffers a collision with an atom, and this energy is released in the radiant form, it is termed "bremsstrahlung," literally "the deceleration or braking radiation.") The soft radiation detected would therefore have been created in the atmosphere rather than incident upon it from outside, as in the case of low-energy cosmic rays themselves.

In the course of the first few months of the IGY, two series of cosmic-ray balloon flights have demonstrated that soft radiation is sometimes present at much lower altitudes in the atmosphere. One series of 20 flights launched at Minneapolis during July, August, and September 1957 was conducted by E. P. Ney and J. R. Winckler of the University of Minnesota to provide week-by-week checks of cosmic-ray intensity and also to coordinate with other IGY cosmic-ray balloon programs in the field. Among the latter was a series of flights at Fort Churchill under the direction of Kinsey Anderson of the State University of Iowa. The following is a brief summary of some of the more significant observations of soft radiation and associated events made on these flights. Recent IGY rockoon observations of auroral soft radiation, made by Van Allen, were reported in *Bulletin No. 5, November 1957*.

The high level of solar activity during the beginning of the IGY produced a number of auroral displays of great intensity. During three of them, on July 1, September 12, and September 21–22, 1957, the Minnesota workers were successful in placing a balloon at high altitude during the aurora and observing soft radiation at levels corresponding to pressures from 8 gm/cm^2 to 40 gm/cm^2. (In an isothermal atmosphere at 273°K, or 0°C, these pressures would correspond to altitudes of 38.9 km and 26.1 km, respectively. At higher or lower absolute temperatures, the corresponding altitudes are proportionally greater or lower than those cited.) Instruments flown on these occasions were an ionization chamber, a single Geiger counter, and, on September 22, a special photon counter.

J. R. Winckler and L. Peterson of Minnesota have reported that during the flight of July 1 an aurora began at 0330Z while the balloon was floating at the 8 gm/cm^2 level. A large initial ionization burst of ten minutes' duration occurred, followed by a weaker one lasting fifteen minutes and another, still weaker, peaked at 0420Z. Fluctuations were seen until 0630Z in both the ionization chamber and Geiger counter. The large initial effect was associated with auroral rays near the zenith, and the increases in rates were roughly correlated with visual observations of increased brilliance near the zenith.

It should be emphasized that this was the first recorded instance of a directly observ-

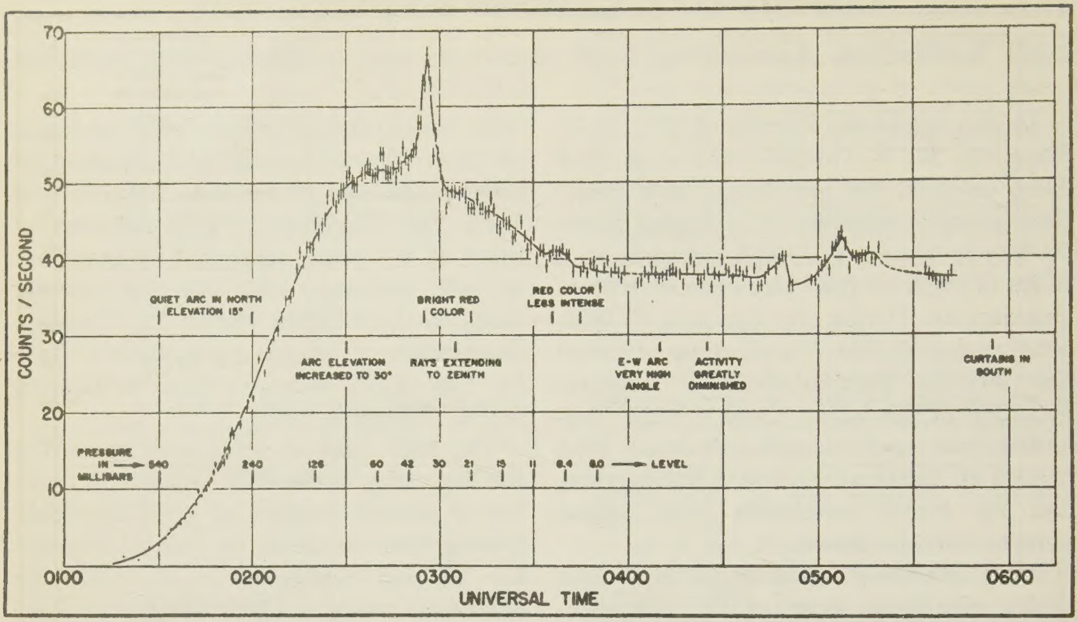

Fig. 2. Geiger counter record taken on a balloon flight at Minneapolis during the auroral display of September 12, 1957. One millibar of pressure is equivalent to 1.08 gm/cm².

able correlation of visual aurora and soft radiation, although, as noted above, the distribution and variation of the kind of radiation observed by Van Allen some years earlier implied a close connection with visual auroras.

In Figure 2, the graph of Geiger counter data obtained on September 12 shows a clear correlation with visual auroral phenomena. A smooth steep rise, middle altitude maximum, and decline to a steady counting rate is typical of a quiet-day record as the balloon rises to altitude. On this day, however, a large increase occurred at the relatively low level of 40 gm/cm²; other deviations from quiet-day behavior are shown by the fluctuations of the line drawn through the observational points. A peak X-ray intensity above the atmosphere of 500 milliroentgens/hour was estimated from data obtained on this flight.

In the July 1 experiment, both the integrating ionization chamber and single counter recorded strong bursts with large fluctuations. The ratio of the two rates—the relative mean ionization per count—varied from 0.2 to 0.26 prior to the commencement of the auroral effect, but during this effect the ratio of the excess rates was 1.3 to 1.4. The value of 0.2 is characteristic of fast, singly-charged particles in the lower atmosphere, while the increase to 0.26 at higher altitude was attributed to increased flux of heavy primary nuclei at those levels. Laboratory studies of the ratio of ionization per count for X-rays of various energies and for gamma-rays showed that the experimental observation of a ratio of 1.4 under 8 gm/cm² of atmosphere is consistent with X-rays in the energy range 50–70 kev. These X-rays are attributed to electrons moving at one-half the velocity of light and emitting bremsstrahlung in the high atmosphere.

A balloon flight made from Fort Churchill, Manitoba, directed by Kinsey Anderson on August 29, 1957, has provided other remarkable evidence of the close interrelations of cosmic rays, soft radiation, and geomagnetic activity—although in this case no direct relationship with auroras was demonstrated. The balloon was instrumented with a vertical-counter telescope, a single counter, and a Neher-type ionization chamber.

A record of the data obtained is presented in Figure 3. The level at time A is the steady pre-storm cosmic-ray level; at B, soft radia-

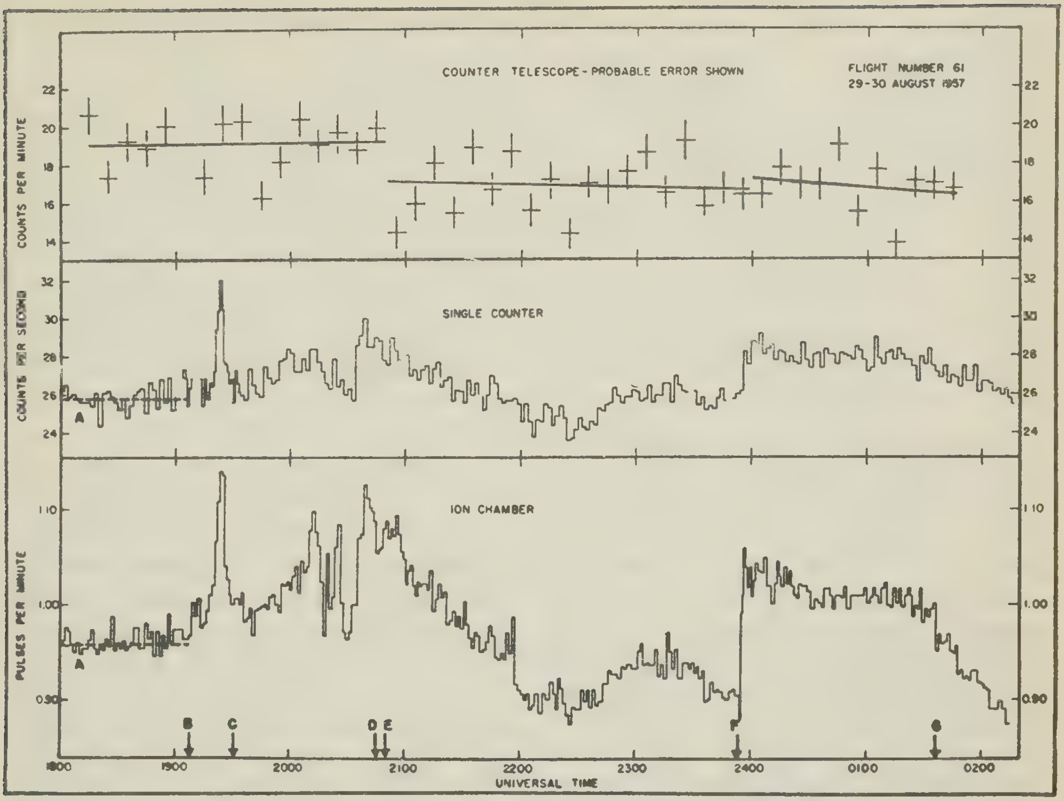

Fig. 3 Cosmic-ray and soft-radiation intensities over Ft. Churchill during the magnetic storm of August 29, 1957. (Reprinted from Journal of Geophysical Research, vol. 62, No. 4 [1957]).

tion begins to appear in both the single-counter and ionization-chamber records at the time when a magnetic storm commenced outside the auroral zone. The subsequent fluctuations of soft radiation, as shown by these records, were accompanied by a magnetic storm with changes in field as large as 400 or 500 gammas, beginning at Fort Churchill at time C. An intense burst of 30-mc radio noise was observed there at time D. An abrupt Forbush-type decrease depressed the counting rates of all these instruments after time E, but a very sharp increase in soft radiation took place at time F; it should be noted, however, that since the ionization chamber and single counter also count soft radiation, the drop at this time is not so apparent in them as in the counter telescope. It was accompanied by a large and rapid decrease of the vertical component of the earth's magnetic field observed at Fort Churchill. At time G, the sun set on the balloon, which began to sink rapidly. No unusual auroral activity was observed, except for a stationary region of low intensity on the evening of August 30, although a display of rayed bands was seen the following night.

The stopping power of the vertical counter telescope was less than that of the ionization chamber. Hence, incoming soft radiation in the form of charged particles should have been observed in it as well as in the other two instruments. It is therefore significant that no soft radiation was observed in the vertical counter telescope, and it was concluded that the soft radiation could only consist of X-rays with energies no greater than 700 kev.

Simulation experiments with X-ray sources at the State University of Iowa have shown that the relative response of the ionization chamber and single counter could be reproduced by X-rays of approximately

100 kev energy. Thus, as in the Minnesota experiments, the X-radiation observed in the Iowa studies is also attributed to bremsstrahlung from electrons incident upon the atmosphere from outside. Anderson remarks that the auroral-associated soft radiation observed by the Minnesota workers and the radiation he observed at balloon altitudes during the magnetic storm are not necessarily identical with that observed in the earlier rocket experiments by Van Allen at higher altitude. (The X-rays that penetrate to balloon altitude are associated with the very active auroral displays which appear in the sub-auroral zones as well as in the auroral zones. In all of Van Allen's rocket studies the radiation was found above balloon altitude and only in the auroral zone.) Winckler and Peterson concur, commenting that although theirs is possibly the same phenomenon as Van Allen's, it is correlated with visual auroras for the first time, and in addition appears to be a more energetic process.

The hypothesis that electrons are responsible for the creation of soft radiation raises the question of their origin. Winckler and Peterson favor the assumption that the soft radiation observed in their experiment originates from 60 kev electrons, and that if these cannot be contained within an incoming auroral beam itself some mechanism must be postulated for transferring energy from auroral protons to the electrons. They note that P. J. Kellogg of the University of Minnesota has suggested the charge separation of the neutral auroral beam on entry into the earth's magnetic field as the means by which the electron component is accelerated from its beam-velocity energy of 30 kev to the observed 60 kev.

Anderson concludes that at least two features of his data strongly suggest that electrons presumed to give rise to X-rays are accelerated near the earth's surface rather than on the sun, although the possibility of local release of the electrons from solar streams is not excluded. These features are: the short time required for the radiation to change its intensity markedly (as at time F in Figure 3), and the simultaneity of changes in the soft radiation with the large storm-type decreases in the earth's magnetic field.

Earth-Strain Measurements in South America

Two fused-quartz extensometers, relatively new instruments for measuring earth strain, have been installed at locations in the Andes Mountains as part of the US-IGY program in seismology. The project is directed by Hugo Benioff of the California Institute of Technology. The observing stations are operated by the University of Chile and the Peruvian National Committee for the IGY.

Standard seismometers, which have been used since the late 19th century, record ground motion during the passage of elastic waves, whose source may be either an earthquake or an artificial explosion. The extensometer, or strain seismometer, on the other hand, measures the differential motion between two nearby points (the ends of the extensometer). The change in the length of the extensometer, either increase or decrease, when divided by the original length, represents the change in strain.

The first extensometer employed for routine observations was designed and installed by Benioff more than 20 years ago. This instrument used an iron pipe as a length standard and a moving-coil-type electromechanical transducer. About 10 years ago, a redesigned version, using a fused-quartz rod as a length standard and a capacity bridge transducer, was installed at Isabella, California. The quartz rod

greatly reduces undesirable variants caused by temperature fluctuations, and the capacity bridge increases the response of the extensometer to include waves of very low frequencies (or long periods). The South American extensometers are of this type.

The extensometers will provide three kinds of observational data: measurements of secular (long-range) strain changes occurring in the great Andes mountain range; measurements of the tidal (diurnal) strains of the earth produced by the gravitational action of the sun and moon; recordings of ultra-long-period seismic waves, including possible free vibrations of the earth excited by earthquakes.

Measurements of secular strains and their accumulation, made at an adequate number of stations over a long interval of time, may yield sufficient information to determine the strain pattern and habit of a region. It is conceivable that such knowledge might ultimately provide a basis for the prediction of earthquakes. The time required for such a study, however, might well run into several centuries.

Measurements of tidal strain provide information on the elastic and plastic properties of the outermost portion of the earth. The long-period waves yield information concerning the mantle and core of the earth as well as the mechanism of the generation of earthquakes.

One of the new extensometers is located at San Cristobal, in the outskirts of Santiago, Chile; the other is in Chosica, a small settlement some 20 miles from Lima, Peru. The University of Chile, at Santiago, and the Peruvian National Committee for IGY, at Chosica, have excavated the tunnels in which the instruments are located, are providing electric power at the sites, and are supplying personnel for the operation of the stations.

Cinna Lomnitz, a member of the staff at the University of Chile, is local scientific advisor for the Santiago work. J. A. Broggi, Chairman of the Peruvian National Committee for IGY, is the scientific advisor at Chosica.

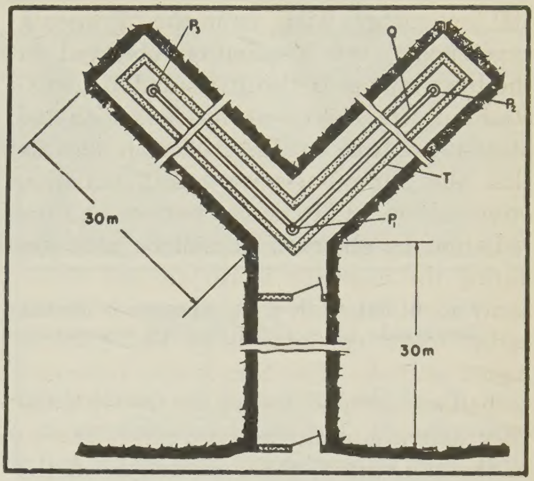

Fig. 4. *Schematic Plan View of the Extensometer Installation at Chosica, Peru.*

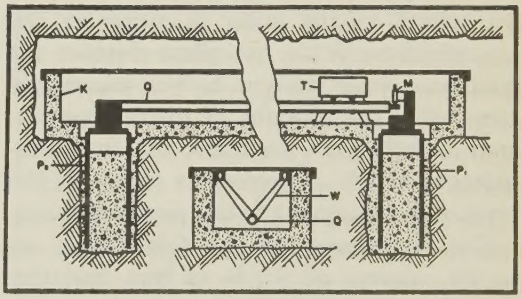

Fig. 5. *Schematic Vertical Section of One Extensometer Component.*

Each installation consists of two horizontal extensometers mounted at right angles in tunnels bored into igneous rock (see Fig. 4). The length standards are constructed of fused-quartz tubing with outside diameters of 2.5 inches, 0.25-inch walls, and lengths of 25 meters.

The mounting of the standards is shown above in a schematic vertical section through one component (Fig. 5). P_1 and P_2 are piers constructed of sections of 12-inch steel pipe sunk into the rock and cemented in with concrete. The quartz standard, Q, is rigidly fastened to one pier and is supported by a series of stainless steel wires, as shown by W in the inset. These prevent transverse movements of the quartz standards without exerting effective longitudinal constraints. Secular measurements are made with the measuring microscope, M, mounted on the

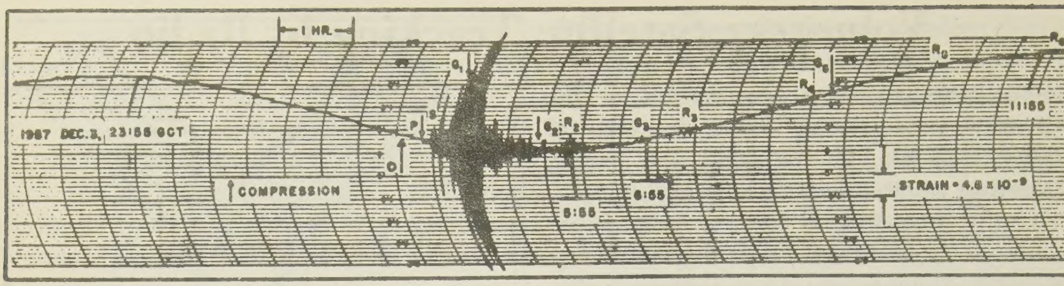

Fig. 6. *Record from Extensometer at Isabella, California. Vibrations set up by the Mongolian Earthquake (Δ = 10,000 km) are superimposed on the trace of the semidiurnal earth tide.*

pier, P_1, at the junction of the quartz standards (Fig. 4). The microscope focuses on a graduated glass scale mounted on the end of the quartz tube. (There are actually two microscopes at P_1, one for each quartz standard.)

Changes in the state of strain in the ground between the two piers displace the graduated scale relative to the microscope cross-hair. The amount of displacement is read directly from the scale, and the corresponding strain increment is given by the ratio of displacement to the pier separation.

The transducer for the tidal strain recorder, shown at T, is of the variable-capacity, resonant-bridge type and operates with a carrier frequency of 5 mc. It is constructed with transistors exclusively. Output from the transducer actuates the ink-writing recorder.

Fused quartz was chosen for the standards because of its low thermal expansion (about 5×10^{-7} per degree C) which, with the expected annual temperature variation within the tunnel of not more than one or two tenths of a degree, should permit secular strains to be measured with an accuracy of approximately one part in 10^7. However, since the diurnal temperature variation of the tunnel is very much smaller, tidal strains can actually be measured to within about one part in 10^9.

Recordings made with the extensometer tidal-strain recorder at Isabella, California, indicate that the sensitivity of the transducer recorder assembly is such that one division on the record represents a strain increment of 8.6×10^{-10}—equivalent to $\frac{1}{10}$ inch in 2000 mi. The South American tidal strain recorders are similar to this one in design and are expected to produce similar recordings.

Figure 6 is a record from the Isabella instrument showing the twelve-hour tidal period for December 4, 1957. Superimposed are the strains from the large (magnitude 8.5) Mongolian earthquake of the same date. The letters G and R on the record refer to Love- and Rayleigh-type seismic waves, respectively. These waves have travelled along the outermost portion of the earth's mantle, just beneath the relatively thin crust (10–50 km thick), from their earthquake source to the instrument site. Such waves travel outward from the disturbance in all directions, commonly circling the earth a number of times.

Love waves travelling the shortest arc to the instrument (10,500 km) are here designated G_1. Love waves travelling the longest arc (29,500 km) are designated G_2 and Rayleigh waves travelling the longest arc are designated R_2. The second passages of the short-arc waves are shown by G_3 and R_3, and of the long-arc waves by G_4 and R_4. Symbols representing subsequent passages have correspondingly higher subscripts. The time of origin of the quake is represented by 0. P and S indicate the first arrival of compressional and shear waves, respectively, which have penetrated the mantle to considerable depth.

Volunteer Satellite Tracking by Radio

The primary method employed in the US-IGY program for radio tracking of earth satellites is the Minitrack system described in *Bulletin No. 2, August 1957.* Two other tracking systems are also in use in a volunteer supporting program designated Moonbeam. One, a simplified version of the prime Minitrack system, is designated Minitrack Mark II. The other, developed by the Jet Propulsion Laboratory of the California Institute of Technology, is called Microlock. It is used in conjunction with the JPL receiving system. Like Minitrack, both Minitrack Mark II and Microlock use the interferometer principle (measurement of the phase difference of signals received simultaneously at different antennas) to determine the angular position of the satellite. The principle of angular position determination by interferometer measurement is explained in the report cited above.

Minitrack Mark II

The Minitrack Mark II is a relatively inexpensive system which can be built and installed with the resources available to many serious volunteer groups. The Mark II system in its simplest form is diagrammed in Figure 7. In this form, the Mark II provides only a meter indication of the presence and passage of the satellite.

This basic system can be modified to provide information accurate enough to be used in computing orbits. A block diagram of such a modified system is shown in Figure 8. When 1000-foot baselines are used and a precise time signal is recorded simultaneously with the interferometer data, this system can give time indications of satellite positions for approximately each quarter of a degree of satellite travel parallel to the base line.

Although the phase difference data recorded by the Minitrack Mark II system may give ambiguous positions, these ambiguities can be resolved at the Computing Center by reference to data gathered by prime Minitrack stations.

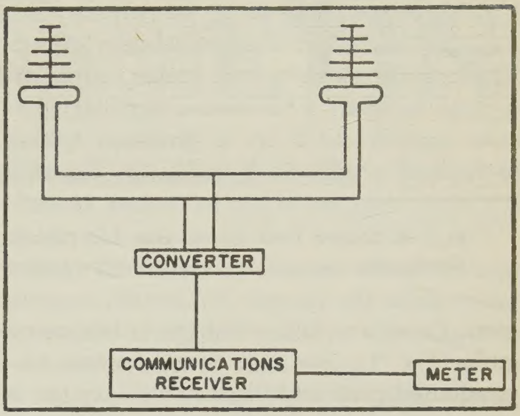

Fig. 7. *Simplest Form of Mark II Minitrack System.*

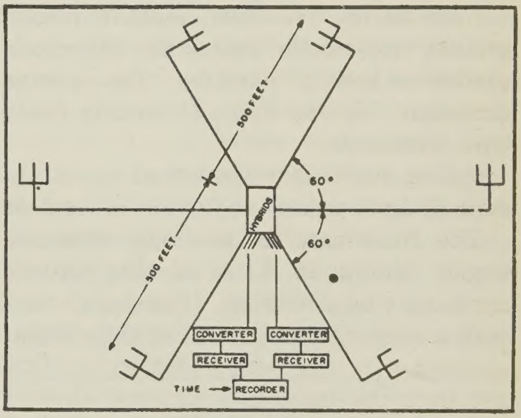

Fig. 8. *Advanced Mark II Minitrack System*

Minitrack Mark II stations are capable of tracking both the 10-milliwatt and the 60-milliwatt transmitters of 1958α to an accuracy of 45 seconds of arc and one millisecond in time. The 10-mw signal at 108.00 mc is preferred for accuracy in tracking, but the 60-mw signal at 108.03 mc is more easily received by most volunteer stations. To be of scientific value, a volunteer radio observation should be accurate to at least one milliradian, or 3½ minutes of arc.

Microlock

The Microlock system uses a variety of antenna arrangements. For the tracking of 1957α2 three antennas arranged in a right triangle were used. The antenna forming the

vertex of the triangle is used as a common point in combination with either of the other two antennas, depending on whether an east-west or a north-south base line is needed. The receiver uses two very stable communications receivers with several auxiliary circuits supplemented by a precision timing source and a calibration oscillator. Figure 9 is a block diagram of the Microlock system.

The distinctive feature of the Microlock receiver is the use of a phase-locked system which shifts the 10-cycle bandwidth receiver automatically to follow changes in frequency caused by Doppler shift or transmitter-frequency drift. A byproduct of this system is an automatic recording of Doppler data. Figure 10 shows the basic phase-locked loop. The use of the phase-locked system and the narrow (10-cycle) radio-frequency tracking bandwidth makes the Microlock receiver extremely sensitive. The narrow bandwidth has the effect of cutting down extraneous noise.

The receiver has a theoretical capability of tracking a device radiating one mw of power at 108 mc at a line-of-sight distance of 3000 mi. The Microlock tracking stations at Earthquake Valley, Pasadena, and Temple City, California, and at Cape Canaveral, Florida, have tracked the 10-mw signal of 1958α at even greater distances.

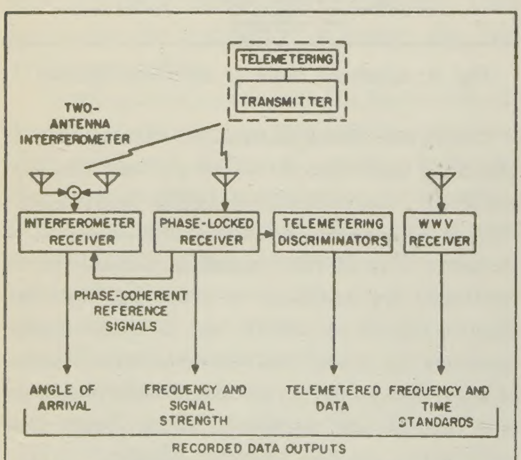

Fig. 9. *Block Diagram of Microlock System*

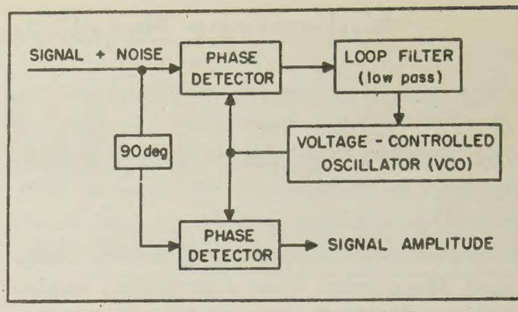

Fig. 10. *Basic Phase-Locked Loop*

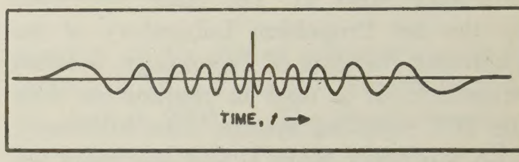

Fig. 11. *Interferometer Signal During Satellite Transit.*

The output of the tracking receiver and a time reference are fed into a pen recording trace from which the time of crossing of the meridian or parallel can be derived. Figure 11 shows a typical trace of a satellite passage.

The Microlock receiving system can also be used to receive 40-mc signals, one of the frequencies used by USSR satellites. To convert the system to reception of 40 mc, add a mixer to accept the 40-mc signals from the antenna. The communications receiver is then tuned to the difference frequency (2.3 mc) between the 40-mc signal and the output of the local oscillator (42.3 mc). With these changes the system will track the 40-mc satellite transmitter in the same manner as described above for the 108-mc transmitter.

Individuals and groups interested in participating in the Moonbeam volunteer radio tracking program may obtain information on the program by writing the National Academy of Sciences, IGY Earth Satellite Office, 2101 Constitution Ave., Washington 25, D. C.

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